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GROUND WATER: WELL DRILLING AND WATER LIFTING EQUIPMENT

By H. A. HETHERINGTON,
M.I.C.E., M.I.W.E., F.G.S.

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GROUND WATER
WELL DRILLING AND WATER LIFTING EQUIPMENT

H.A.HETHERINGTON M.I.C.E.,
M.I.W.E., F.G.S.

INTRODUCTION:

1. In most countries ground water supplies have been developed to some extent but there are still areas where only extremely shallow wells have been constructed and little or no real ground water abstraction has taken place.

2. These countries are generally those in which the harder rocks predominate, but even in areas of sedimentary deposits modern well drilling techniques have not always been used to the fullest extent and it is the smaller villages and rural communities which have not benefited from the relatively cheap methods of ground water development which are available.

3. Drilling carried out on the smallest scale, utilising only one or two rigs, can be of material benefit and the results obtained, though not spectacular, can be of considerable help in raising the standard of living.

4. In this paper a brief description is given of the plant available for the development of rural and small town water supplies and the types of pumping plant commonly used.

GEOLOGY AND HYDROGEOLOGY:

5. The geological and hydrogeological conditions obtaining in a country are matters which require the first consideration when planning any ground water development scheme, however modest.

6. The nature of the rock to be penetrated will determine to some extent the type of equipment to be utilised and the form of well to be constructed.

7. The depth to water will also have to be considered and the quantity of water likely to be obtained from the particular aquifer being developed.

8. The quality of water to be obtained will determine the constructional materials for use in the borehole. If the water or soil is corrosive special equipment will be required for the lining and screen and must be provided for. The possibility of saline water being met with at lower levels will also affect the depth of the borehole and must be taken into consideration.

9. The following table indicates the range of yield which may be expected from 6" to 8" diameter borings sunk in the type of formation frequently met with in less developed areas.

"TABLE 1"

Geological Formations	Dia. of borehole	Average Range of Depth	Average range of yield in G.P.H.
Weathered granite	6"/8"	100 ft./300 ft	100 to 6,000
Weathered gneiss	6"/8"	50 ft./150 ft	100 to 3,000
Quartzite & quartzitic Sandstone	6"/8"	100 ft./600 ft	100 to 1,200
Shales & tillite	6"/8"	under 100 ft	up to 1,600
Dolomite (Transvall System)	6"/8"	75 ft./100 ft	800 to 1,200
Limestone	6"/8"	150 ft./500 ft	1,000 to 7,000
Sandstones	6"/8"	200 ft./900 ft	3,000 to 12,000
Alluvial & recent sand deposits	6"/8"	200 ft./350 ft	5,000 to 20,000

METHODS OF WATER WELL DRILLING:

10. Water well drilling is carried out by either the percussion or the rotary systems of boring and occasionally by a combination of both methods.

11. As their names imply, in the percussion system penetration is obtained by breaking up the formation by the percussive action of a chisel or bit, the debris being recovered by a bailer, and in the rotary, the formation is broken by the rotational action of a rock roller, or drag bit and the cuttings removed by the circulation of specially prepared mud, or in certain cases by water alone.

PERCUSSION DRILLING:

12. Percussion drilling may be carried out with rod or cable tools and portable trailer or truck mounted cable rigs; with sheerlegs and friction winch, or when drilling is required in soft clays and sands with hand plant utilising a bailer only, and sinking the casing with kentledge.

13. Rod drilling is gradually being superseded by cable drilling except for the construction of large diameter boreholes which are outside the scope of this paper.

14. Trailer mounted rigs are the most commonly used type of water well equipment. Their cost will depend upon the size and depth of bore to be drilled but for rural water well development a rig to drill a 6"/10" diameter borehole to 500 feet would be satisfactory and would cost between £3,000 and £4,000.

15. A set of drilling tools, wire lines and fishing tools for use with the rig would cost a further £2,000.

16. Sheer legs and a friction winch, easily transportable to areas of restricted access cost only some £1,000 per set.

17. The cheapest of all types of percussion equipment which can be used for sinking wells in sands and soft clays, as in India, Pakistan and Egypt, consist merely of a set of sheerlegs of wood or tubular construction, casing of the required diameter, rope or wire line and a bailer for bringing up the sand and clays from inside the casing as it is sunk by the weight of kentledge or sandbags.

18. The use of hand equipment of this latter type while slow in construction is extremely cheap.

19. A power operated grab is also used occasionally for the construction of large diameter shallow bores but is a type of drilling not in common use and is only applicable for working in soft rock formations.

ROTARY DRILLING:

20. Rotary drilling may be conveniently divided into the following basic types.

(a) Mud flush rotary
(b) Water flush rotary
(c) Reverse circulation rotary
(d) Shot rotary

21. Trailer or truck mounted mud flush rotary rigs of a light type are suitable for rural water development but they are more expensive to run than percussion rigs and are generally only used for the construction of boreholes over 300 feet in depth in unconsolidated strata. A rig to drill to 1,000 feet would cost between £11,000 and £12,000. The cost of supplying water and mud can in certain areas be heavy.

22. Water flush rotary equipment consisting of a derrick, drill rod, usually steam quality pipe, flush jointed casing and a centrifugal pump is an inexpensive outfit for use in drilling in sands and clays where a source of water supply for drilling purposes is readily available. The bit used is usually a drag bit or fishtail type and the rods are turned by hand.

23. The whole equipment for sinking 6" bores to 300 feet costs approximately £2,000 and is very suitable for drilling in areas such as lower Bengal, East Pakistan, the Nile Delta and areas of similar geological formation where surface water can readily be obtained for drilling purposes.

24. Smaller outfits for jetting 4" casing can be supplied even more cheaply and this method is particularly successful where water is found in sands at shallow depths and only small diameter boreholes are required, water being within suction lift.

25. The reverse circulation method of drilling in which, as its name implies, the drilling fluid, in this case water, is drawn up the drill pipe and the make up water, which must maintain the borehole full to surface level, is fed directly into the borehole, is not particularly suited to rural development, unless in connection with irrigation.

26. For irrigation wells however to be constructed in sands and clays it is probably the most effective method of drilling which has yet been developed.

27. Reverse circulation drilling requires large quantities of make up water and is particularly suitable therefore where a major drilling programme is to be carried out, so that if necessary water can be pumped from one site to the next.

28. Shot rotary is virtually only used at the present time where large diameter boreholes are to be sunk in sandstones, quarzites and crystalline limestone formations. It has the merit that cores are obtained for geological classification, and the equipment is inexpensive compared to the equivalent size of mud flush rotary plant.

29. In Morocco a number of wells have recently been drilled using air in place of the conventional mud or water as a flushing medium and successful results were obtained.

30. Air is not yet in general use however for water well drilling as it cannot support unstable strata and difficulties are encountered in dealing with water inflows.

31. A further application of the use of air is with the Down-the-hole hammer drills.. A pneumatically operated percussion rock drill is attached to the bottom of the drill pipe and rotated slowly during drilling. Rapid progress can be made in hard rocks but the system is unsuitable for soft rocks.

COMBINATION RIGS:

32. Because of the special advantages of the use of percussion in one forma-

tion and rotary in another, combination rigs which incorporate the equipment for both methods have been designed. With such rigs a rapid change may be made from one method of drilling to another. Combination rigs are not however widely in use.

SELECTION OF DRILLING EQUIPMENT:

33. The selection of drilling equipment for use in any individual area will depend upon the topography, geology, rate of drilling required, quantity of water available for drilling purposes and availability of skilled personnel; the diameter and depth required will also have to be taken into consideration.

34. The depth of the bore will be determined by the hydrogeological conditions obtaining at the site, and the diameter by the yield expected or required and the type of pump to be inserted.

35. Percussion drilling is applicable to all types of formations but is slow in unstable materials such as dune sands, quicksands, and soft clays as casing has to be used to prevent caving.

36. With rotary equipment rapid drilling is possible in most formations. The use of mud enables unstable strata to be handled satisfactorily and rapidly but for shallow wells percussion equipment may be preferred.

37. In cavernous and extremely permeable lost circulation zones rotary tools are unsatisfactory owing to the difficulty of maintaining a return flow.

38. Alluvial formations consisting of boulders, cobbles and coarse gravels are difficult to drill with any equipment but the cable tool percussion method is the most suitable.

39. Metamorphic and igneous rocks can be handled by both methods of drilling but for shallow depths in undeveloped countries the percussion method is likely to give the best overall results.

40. The following table may be used as a guide to the choice of drilling equipment.

"TABLE 2"

Drilling method	Usual dia. range	Depth range	Optimum rock type	Drilling water requirements per 8 hr shift
				gallons
Hand percussion (sludger method)	6"/15"	50/400 ft	Sands & soft clays	100/150
Rod percussion	6"/24"	50/200 ft	All formations except hard rock	100/150
Cable percussion	6"/21"	50/500 ft	All stable formations	100/150
Mud flush rotary	4"/18"	300/1500 ft	All formations except boulders chert and cavernous limestone	750/15000
Water flush rotary	6"/8"	50/500 ft	Sands and soft clays	10000/50000
Water flush jetting	4"/6"	50/100 ft	Sands and soft clays	500/1000
Reverse circulation	15"/60"	100/450 ft	Sands, gravels and soft clays	30000/50000
Shot rotary	6"/36"	50/500 ft	Igneous rocks, sandstones & crystalline limestones	4000/8000

DRILLING RATES:

41. Drilling rates as such are of little real value as so many factors can affect them. The following footage rates and overall monthly average based on a number of months working however may be of use in planning a drilling programme.

"TABLE 3"

Formation	Av. footage per month in completed boreholes.	Drilling Method
Sand and Gravel	309 ft.	Percussion
Weathered granites and schists	123 ft.	Percussion
Sandstones	316 ft.	Mud Rotary
Sandstones and shales	1,100 ft. x	Mud Rotary
Limestone	398 ft.	Percussion
Clay, shale and sand	319 ft.	Mud Rotary
Clay, shale and sand	210 ft.	Percussion
	x 3 shift working	

42. The rates given in table 3 include moving between sites and insertion of casing and screens where applicable.

43. Costs of drilling will, depend upon the strata to be drilled, the area in which the work is to be carried out and the number, diameter, depth and spacing of the bores.

44. Costs generally will range between £3 and £10 per foot.

BOREHOLE CASING:

45. All boreholes require lining if only for the upper 20 feet to 50 feet as a means of protection against immediate pollution, and where possible should be grouted externally.

46. If the strata to be supported and water obtained are not corrosive steel well casing to A.P.I. or a water well standard should be used.

47. Where corrosion is likely, cast iron or semi steel lining may be used if available locally. Alternatively plastic pipes may be used for small diameters, asbestos cement up to 11 inch internal diameter and glass fibre reinforced polyester casings for diameters up to 24 inch. Wood and compressed bakelized wood may also be used in sizes up to approximately 23 inch internal diameter. If greater strength is required for deep wells steel pipes plastic coated will be found to be satisfactory.

SAND SCREENS:

48. In unconsolidated strata some form of slotted pipe or screen is required with or without gravel packing.

49. A vast variety of screen is available and the choice will largely be a matter of personal opinion.

50. Screens should be inserted with a sand trap at the base and designed so that the entry velocity of the water is as low as possible.

51. Prepacked screens in which a fine gravel is bonded to a plastic coated steel screen have proved effective but care is required in handling them.

52. Where a mobile gravel pack is used the gravel should be clean, well rounded and carefully graded in relation to the sand to be retained.

DEVELOPMENT OF BOREHOLES:

53. The yield of almost all boreholes can be improved on completion by the adoption of one or more of the following development techniques:

(a) Swabbing
(b) Backblowing
(c) Acid treatment
(d) Calgon treatment
(e) Pressure fracturing
(f) Shot firing

54. Swabbing or surging (with a surge plunger) is one of the most effective and cheapest methods of developing boreholes in all types of formation. The swab or plunger is operated up and down a borehole under about 15 foot of water for a period determined by the driller. The swab is then withdrawn and the hole cleaned out and the process repeated until no further sand or cuttings are brought into the borehole. Increases in yield of up to 1,000% have been obtained.

55. Backblowing requires the use of a compressor to force the water back into the fissures or through the screen. By building up a pressure and suddenly releasing it an effective washing action is obtained. Increase in yield with this method of development range from 30% to 50%.

56. In limestones and chalks very considerable increases in yield can be obtained by treating boreholes with acid. The quantity of acid will range from 3 to 40 tons and increases in yield of up to 700% may be expected.

57. Calgon is used primarily to disperse drilling mud but also to increase the yields of old wells which have fallen off, due to plugging with minerals deposited by the water, or with clay and silt. Increases of yield of up to 300% have been recorded.

58. Pressure fracturing, an oil field technique, has been successfully used in South Africa to obtain increased supplies of ground water from low permeability rocks. The fracturing is achieved by pumping or tamping a viscous fluid sand suspension into the borehole. Increases in yield of 300-400% have been obtained with in one recorded case an increase of 1,100%.

59. The yield of boreholes sunk in sand rocks may often be increased by shattering the rock through the explosive force of small charges of gelignite. Directional charges may also be used in certain circumstances where it is necessary to perforate casing in situ. Increases in yield of 200-300% have been obtained but diminution in yield can also occur by stemming clayey or marley material into fissures.

PUMPING PLANT:

60. Pumping plant for small scale ground water supplies must be simple to operate and in respect of hand plant must be as robust as is commensurate with an economic price.

61. For small village supplies hand pumps are adequate. The semi rotary type being suitable for use where water is within suction lift, and the deep well type where water levels are lower.

62. A pump which has proved suitable for village supplies is one fitted with a heavy flywheel with detachable handle and bolted on balance weight. Yields of 70 gallons per hour can be pumped from a depth of 200 ft. below surface and yields of 300 gallons per hour from 50 feet.

63. For larger supplies where a distribution system and overhead tank is to be provided power pumps have to be installed.

64. The simplest type is the beam operated deep well reciprocating pump driven by belt from an oil engine. Alternative types of pump head are the totally enclosed oil bath type.

65. For supplies of over 3,000 gallons per hour submersible and turbine pumps are the most suitable to install.

66. To operate submersible pumps an alternating current electric supply has to be made available but turbine pumps may be driven from oil engines if required through gear heads.

67. The jet pump has also proved satisfactory for pumping small supplies of water from boreholes in rural areas.

68. Comparative capacities of borehole pumps are as follows:-

"TABLE 4"

Type of Pump	Deep Well Plunger	Submersible	Turbine	Jet
Dia. of Bore hole	Capacity in Gallons Per Hour			
4"	100/250	100/1,100	2,000/5,000	200/1,300
6"	1,000/2,500	500/8,000	4,500/15,000	500/1,500
8"	3,000/5,000	2,500/15,000	5,000/30,000	1,800/5,000
10"	6,000/9,000	12,000/40,000	15,000/58,000	4,000/10,000
12"	10,000/12,000	14,000/60,000	25,000/75,000	

MAINTENANCE OF BOREHOLES AND PUMPS:

69. A properly constructed borehole should have an almost indefinitely long life.

70. Corrosion of the lining should have been provided against in the construction so that the failure of a bore to continue to yield at its maximum capacity is generally due to overpumping in the vicinity, silting or liming up of fissures, or, in the case of screened wells, chemical precipitation on the openings.

71. Silting or carbonate precipitation can be cured by one or other of the methods mentioned under the development of boreholes.

72. Overpumping should be prevented by controlling the quantity of water to be abstracted from an acquifer so that no depletion of reserves takes place.

73. To maintain the purity of the water the head of the borehole should be adequately protected and where possible the immediate area surrounding the borehole should be fenced off to prevent access of animals.

74. Records should be kept of the standing and pumping water levels together with the quantity of water pumped so that any progressive changes can be noted and the requisite action be taken.

75. Chemical and bacteriological analysis should also be made at regular intervals.

76. The output of the pump should be noted in relation to its speed of operation and power consumption so that remedial action can be taken before serious damage is done. This is particularly important in regard to submersible pumps, and if there is any possibility of the water level falling below the pump, low level cut outs should be provided so that the pump is stopped automatically.

GROUND WATER DEVELOPMENT SCHEMES:

77. A brief description of work carried out recently in connection with the production of ground water as a means of supply to towns and villages in Africa and the Middle East will serve to illustrate the type of results which can be generally expected.

TANGANYIKA:

78. The quantities of water obtained from a number of 6" diameter boreholes sunk in the basement complex rocks of Tanganyika in an endeavour to develop water in a rather unpromising area in which little or no weathering had taken place is tabulated below.

79. The borings were carried out by percussion equipment. Four rigs were employed and the average rate of drilling was 127 feet/rig per month. One European driller was employed on each rig and a drilling Superintendent and Agent were in overall control of the work.

80. The work was carried out by contract and the cost of drilling including test pumping averaged £3.6.0. per foot.

"TABLE 5"

No. of Bores drilled	Bores abandoned yielding less than 200 G.P.H.	Yield of Over 1,000 to 2,000 G.P.H.	Successful Bores 500 to 1,000 G.P.H.	200 to 500 G.P.H.	% success-ful
37	16	3	8	7	48%

81. Until the boreholes were developed the country had been barren as there were no existing sources of water supply.

GHANA:

82. To provide rural water supplies in Ghana 10 cable percussion trailer mounted rigs were employed on a contract basis over a period of 4 years ending in 1957. During the four years work 369 boreholes were drilled, of which 301 were successful in that yields of over 100 gallons of water per hour were obtained.

83. As the work was spread over the whole of the northern territory and the eastern and southern parts of the country the rigs were divided into three groups, two of three rigs and one of four. Each rig was operated by a European driller on a single shift basis and each group was under the supervision of a superintendent, with an agent in Kumasi in overall control.

84. One 3 ton lorry and one water tanker was provided to service each group and in addition each rig had a land rover for the use of the driller and for general servicing.

85. Rigs were towed between sites by the lorry or land rover but for major moves the rigs were transported by low loaders.

86. Reciprocating pumps were provided for testing and were rig operated. In certain cases extended tests were carried out by deep well pumps.

87. Work was undertaken for the most part in isolated areas and in many cases villagers constructed access roads to get the machinery onto the sites.

88. The sites of the majority of the boreholes were selected geophysically by the use of resistivity depth probes.

89. Hand pumps were installed in the boreholes sunk in the smaller villages and power pumps of either the reciprocating deep well or submersible types, in the boreholes sunk to supply the larger villages with piped water supplies.

90. The total quantity of water produced from the boreholes was approximately 420,000 gallons per hour or on an eight hour pumping day approximately 1,226 million gallons of water per annum.

91. Results obtained from five areas of different geological formation in Ghana are shown in table 6.

"TABLE 6"

Geological Formation	Bores Drilled	Failures	Successes	% Success	Depth of bore		Max Yield G.P.H
					Min.	Max.	
Mid devonian and Archeon rocks	24	16	8	33.5%	100'	390'	2,500
Cape Coast Granites	44	3	41	93.0%	65'	273'	2,500
Buem Quartzites and Shales	25	4	21	84.0%	120'	360'	3,000
Tertiary and Eretac -ecus formations	22	9	13	55.0%	147'	478'	3,200
Voltaian Sandstone & shale (Damongo)	12	2	10	83.0%	100'	630'	1,200
Voltaian Sandstone & shale (Kete Krachi)	16	4	12	75.0%	91'	280'	3,600

92. Individual results obtained from the forty-four boreholes drilled in one area of the granite formation are as follows:-

"TABLE 7"

No. of bores	Yield G.P.H.	Percentage of Total
19	100/ 500 G.P.H.	43.2%
5	501/1,000 G.P.H.	11.4%
3	1,001/1,500 G.P.H.	6.8%
8	1,501/2,000 G.P.H.	18.2%
6	2,001/2,500 G.P.H.	13.6%
3	less than 100 G.P.H.	6.8%

NIGERIA:

93. In Eastern Nigeria in an area where boreholes range in depth from 350 feet to 900 feet and water is obtained from sands and sandstones rotary equipment has also proved very effective.

94. One truck mounted rotary rig has recently completed 16 boreholes totalling 8,237 feet of 14" diameter drilling in seven and a half months. The average rate of drilling including borehole completion but excluding test pumping, being at the rate of 14.7 feet per 8 hour shift. The best rate of progress was the completion of one 600 foot borehole in 7 days.

95. The yields obtained ranged from 3,000 gallons per hour to 12,600 gallons per hour.

96. Submersible pumps operated on locally generated power were installed to complete the well stations.

CONCLUSION:

97. The examples which have been quoted of work carried out in areas of different geological formations with both percussion and rotary equipment illustrate in some degree the manner and extent to which ground water may be exploited for the benefit of the less fully developed areas.

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